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# SUPER-WIDEBAND PRINTED ASYMMETRICAL DIPOLE ANTENNA

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**Abstract**—The proposed dipole antenna consists of two printed strips with unequal lengths and is fed by a coplanar strip (CPS) line. As the antenna parameters and port impedance are properly selected, a super wide operating band ($|S_{11}| < -10\,\mathrm{dB}$) of 3.5 to 20.0 GHz is realized. Antenna samples were fabricated using standard PCB process. The area of the constructed dipole antenna is $40.0 \times 5.0\,\mathrm{mm}^2$. The $S$-parameter measurement was performed via a transition (CPS to double-sided parallel strip line) and transformer (190 to 50 Ohm). The measured fractional bandwidth achieved 139.3% (from 3.4 to 19.0 GHz) as predicted, over which the antenna peak gain is better than 0 dBi.

## 1. INTRODUCTION

Traditional dipole antennas have many attractive advantages, such as compact size and ease of design [1]. In general, the operating bandwidth of a dipole antenna with thin arms is narrow, thus blocking itself from application in modern wideband communication systems inclusive of ultra-wideband (UWB) system. In fact, much effort has been made to broaden the initial bandwidth of the traditional dipole antennas [1–6]. One straightforward approach is to enlarge the radiating arms, resulting in the reduction of antenna's quality factor [1]. This approach is simple, but the enhanced bandwidth is still narrow due to its single resonance nature. Another approach is to modify its radiating arms in configuration, e.g., bi-cone and

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bi-sphere antennas. A bi-cone antenna is approximately frequency-independent [1, 2], thus has super-wideband radiation capacity. In parallel, various planar dipole antennas under the principle described above have been studied for about three decades. As the planar version of the bi-sphere antenna, a disk dipole can achieve a fractional bandwidth of 110% or wider [2–7]. However, the dimensions of those modified dipole antennas are much larger than the traditional dipoles with straight arms.

In fact, the offset-feeding technique is an alternative approach for widening the bandwidth of dipole antennas [8, 9]. Comparing with the center-feeding scheme, the offset-feeding can bring more flexibility for wideband impedance matching, especially in the low frequency band [9]. In [9], with an offset rate of 34%, a thick dipole (length/diameter = 7.5) was successfully designed and developed, which achieved an impedance bandwidth of more than 10 : 1. Based on this idea, a printed offset-feeding/asymmetrical dipole is presented in this letter. The proposed antenna has several advantages, such as compact size, light weight and low cost.

## 2. ANTENNA DESIGN

Figure 1 shows the configuration of the printed asymmetrical dipole antenna. The antenna consists of two printed metallic strips with different lengths ($L_f$ and $L$-$L_f$) and identical width ($W$). The feed point is offset from the center of the whole radiator. Near the feed point ($L_c$), the widths of the two strips is set to be much narrower ($W_c$) than those in the far regions ($W$). The coplanar strip (CPS) feeder is connected to the open ends of the narrower strips. The antenna structure is constructed on a Roger 5880 ($\varepsilon_r = 2.2$) substrate of thickness 1.0 mm. The fullwave simulation is carried on using Zeland IE3D. For a wideband antenna without external matching circuit, the port impedance is important, which provides a reference for the varied input impedance of antenna over wideband. Therefore, the port impedance is not fixed as 50 Ohm in this design. The antenna

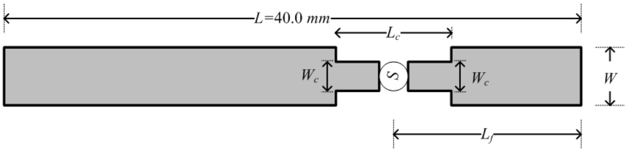


**Figure 1.** Configuration of proposed printed asymmetrical dipole antenna.

design starts with a fixed antenna length $L = 40.0\,\mathrm{mm}$, which is about half wavelength at 3.5 GHz. Other parameters, $W$, $W_c$, $L_f$ and $L_c$, are tunable in the optimization. The optimization goal is to get an antenna with the impedance bandwidth ($|S_{11}| <= 2.0$) of 3.4 to 20.0 GHz. After optimization, antennas with a few sets of parameters are given to show the impacts of each parameter on return loss.

Figure 2 depicts the simulated $|S_{11}|$ with varied port impedance under the same antenna dimension: $L = 40.0$, $W = 5.0$, $L_c = 6.1$, $W_c = 1.0$, $L_f = 15.7\,\mathrm{mm}$. From the figure, it can be found that with port impedance of 190 Ohm, $|S_{11}|$ could be attenuated below $-10\,\mathrm{dB}$ from 3.5 GHz to 20.0 GHz. For comparison, in the case of 50 Ohm, the impedance bandwidth ($|S_{11}| < -10\,\mathrm{dB}$) is about 14.9% (2.91 GHz to 3.38 GHz), which is similar to a traditional narrow-band dipole antenna.

Figure 3 shows the performance of antennas with different configurations. It can be observed that without cutting ($W_c = W$), the return loss curve is similar to a traditional narrow-band dipole. The fractional bandwidth is only 25% ($|S_{11}| < -10\,\mathrm{dB}$). Without offset feeding ($L_f = L/2$), the return loss from 6.0 to 10.0 GHz is raised up to $-7\,\mathrm{dB}$. In comparison, the asymmetrical dipole with cutting achieves the widest bandwidth.

In addition, Fig. 4 shows the impact of the strip width ($W$) on the simulated $|S_{11}|$. It can be observed that $|S_{11}|$ is gradually lowered over 3.4 to 20.0 GHz as the width ($W$) increases. This is because as

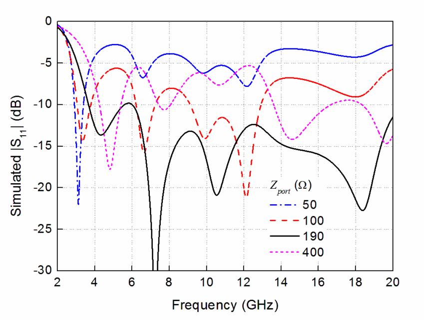


**Figure 2.** Simulated $|S_{11}|$ of proposed antenna with varied port impedance under the same dimension: $L = 40.0$, $W = 5.0$, $L_c = 6.1$, $W_c = 1.0$, $L_f = 15.7\,\mathrm{mm}$.

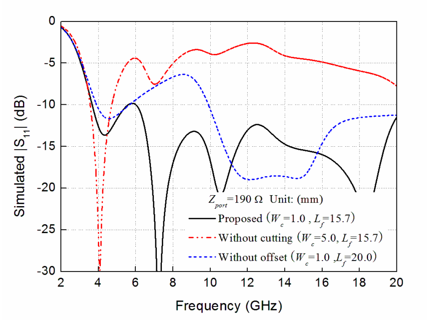


**Figure 3.** Simulated $|S_{11}|$ of proposed antenna ($Z_{port} = 190\,\mathrm{Ohm}$) with different configurations: $L = 40.0$, $L_c = 6.1$, $W = 5.0\,\mathrm{mm}$.

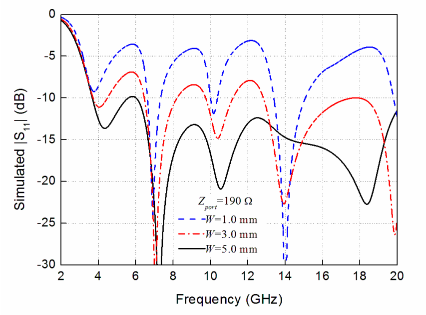
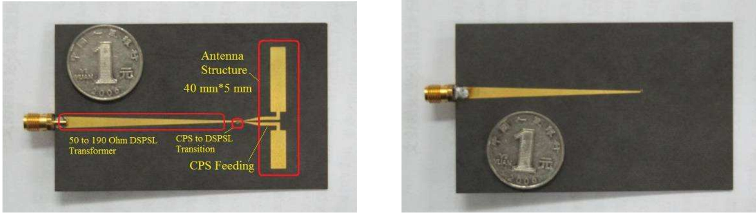


**Figure 4.** Simulated $|S_{11}|$ of proposed antenna ($Z_{port} = 190\,\mathrm{Ohm}$) with varied strip width ($W$) under the same dimension: $L = 40.0$, $L_c = 6.1$, $W_c = 1.0$, $L_f = 15.7\,\mathrm{mm}$.



Top view

Bottom view

**Figure 5.** Photographs of antenna sample.

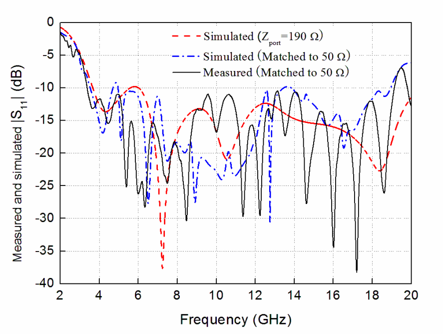


**Figure 6.** Measured and simulated $S$ parameters of proposed antenna.

the strip width increases, the quality factor of each radiating modes decreases. Finally, the antenna parameters are selected as $L = 40.0$, $W = 5.0$, $L_c = 6.1$, $W_c = 1.0$, $L_f = 15.7\,\mathrm{mm}$ and port impedance of $190\,\mathrm{Ohm}$. The planar dimension of this antenna is only $40.0 \times 5.0\,\mathrm{mm}^2$.

According to [1], the equivalent arm diameter is half of the strip width for a planar strip, thus the equivalent length/diameter of this antenna is 40/(5/2) = 16, which is much smaller than the reported thick dipole in [6].

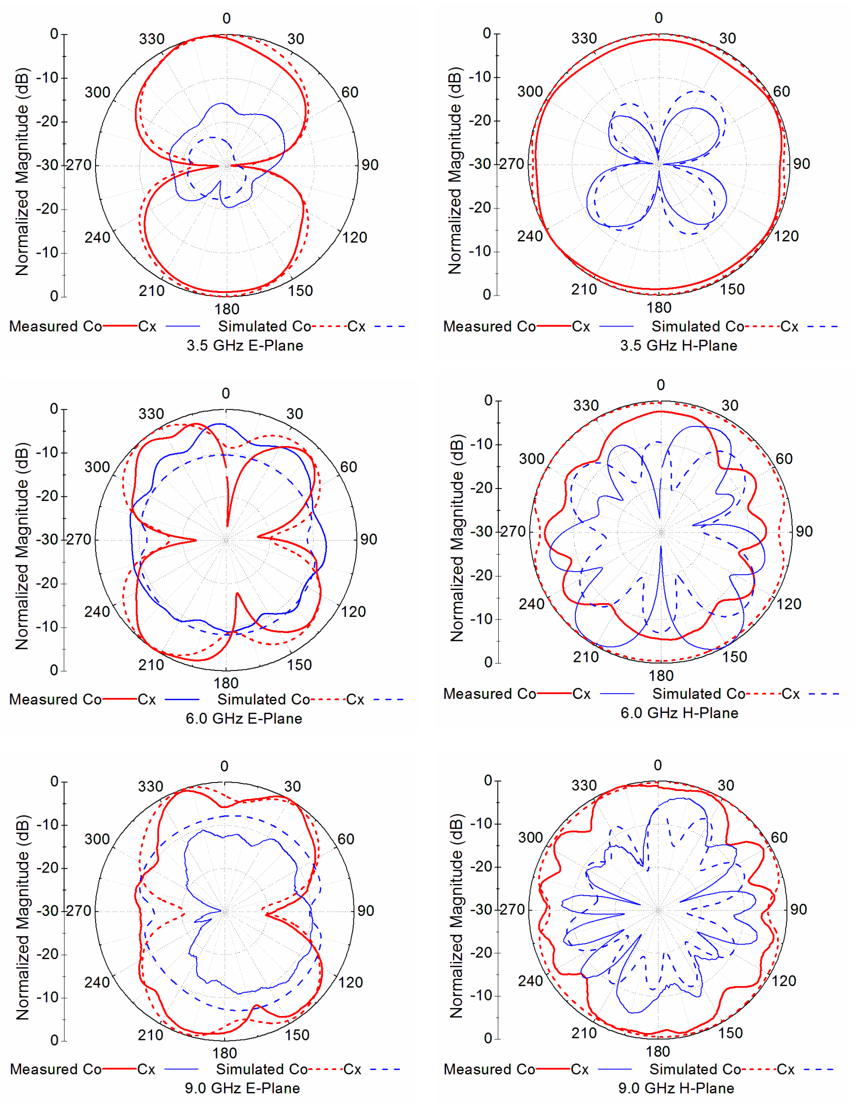


**Figure 7.** Measured and simulated radiation patterns of proposed antenna at 3.5 GHz.

## 3. ANTENNA MEASUREMENT AND RESULTS

As emphasized before, the optimized port impedance of the proposed antenna is 190 Ohm, thus there is a mismatch between the antenna and a standard 50 Ohm network analyzer. A transformer then needs to be designed to perform the $S$ parameter measurement. A transition from CPS to double-side parallel strip line (DSPSL) is also designed and employed for connecting a SMA connector. Antenna samples were fabricated using standard PCB process. The photographs of a fabricated antenna sample are shown in Fig. 5. From Fig. 5, one can find that the transition between the DSPSL and CPS is realized by introducing a metallic via hole. Fig. 6 shows the measured and simulated $S$ parameters. From the figure, it can be observed that the simulated impedance bandwidth is slightly affected after adding the transformer. The reason is that the simulated bandwidth with the transformer is not wide enough (from 3.4 to 19.0 GHz). This could be improved by using a longer transformer (the circuit size will be increased). The measured and simulated $|S_{11}|$ are in good agreement. Fig. 7 shows the measured and simulated radiation patterns at 3.5, 6.0 and 9.0 GHz, respectively. Good agreement between them is achieved. At 3.5 GHz, the cross-polarization is lower than $-10$ dB. At high frequencies, the measured patterns and polarization purity are affected by the impedance transformer. In antenna measurement, the transformer (matching line) becomes an additional scatterer, which generates unwanted reflection and affects the antenna's radiation parameters. The scattered wave is dependent on angle. Also, at high frequencies, the leaky radiation of the matching line itself is enhanced, which can affect the polarization purity. The measured antenna peak gain is over 0 dBi over 3.4 to 19.0 GHz, inclusive of the insertion loss of transformer.

## 4. CONCLUSION

A printed asymmetrical super-wideband dipole antenna is presented, designed and implemented. The antenna is composed of a pair of strips with unequal lengths. Its structure is simple, and the size is small, but it exhibits super-wideband radiation capacity from our extensive numerical and experimental investigation. As a result, a compact dipole antenna was realized practically with an area of $40.0 \times 5.0\,\mathrm{mm}^2$, and it is operated in a frequency range from 3.4 to 19.0 GHz. Both simulated and measured results are given to demonstrate its performance.

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